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Low Energy Particle Sensor for Medium Earth Orbit

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Final Report

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14. ABSTRACT

The Low Energy ElectroStatic Analyzer (LEESA) will measure electrons and protons from 100 eV to 50 keV onboard the DSX spacecraft. This sensor uses hemispherical sector ESAs to achieve a single, 50 degree pitch angle bin. LEESA is a new instrument, based on heritage designs of sensors, analog electronics, and power supply electronics. During the first year of the program, we have carried out a requirements analysis, a concept design phase with trade study, and the preliminary design phase. The results of these are presented.

15. SUBJECT TERMS

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1. INTRODUCTION

LEESA, the Low Energy ElectroStatic Analyzer, will measure the low energy electrons and positive ions in Medium Earth Orbit (MEO) for the DSX mission. These low energy particles are responsible for surface charging of spacecraft surfaces, for charging of the spacecraft frame, and for damage to the outermost layers of thin materials (such as thin film photovoltaics) so are of considerable operational interest. They also provide information on the heating of the plasma environment. LEESA is part of the Space Weather Experiment but will also provide critical information for the Wave-Particle Interaction Experiment, particularly in regards to heating of the local plasma and charging of the spacecraft surfaces.

LEESA is specified to measure electrons and protons from 100 eV to 50 keV, in 20 to 30 logarithmically space energy channels, with a single pitch angle bin, and a field of view (FOV) of 25° to 50°. Amptek has designed and built many instruments which measure this same basic population, each tailored to specific measurement requirements. There are several different ESA configurations which have been flown, each of which is advantageous for a particular class of measurements. For LEESA, Amptek is using the heritage designs to provide the DSX low energy particle sensor. We are developing a new instrument, based on heritage designs for sensors, analog electronics, and power supply electronics, tailored for the specific DSX needs, with new digital processing and serial interface hardware and software.

The first year of the program was divided into two phases. The first six months was a concept design and trade study phase. The primary goal of this phase was to clarify various goals and requirements not explicit in the SOW. The second goal was to assess the capability of the different ESA configurations to meet the goals and requirements. We carried out a trade study of several different concept designs and then selected the optimum, in close coordination with the Air Force technical monitor. The hemispherical sector ESA was chosen as the basic concept. The second six-month period was the preliminary design phase. In this phase, the preliminary design was prepared for all parts of the instrument. This included the sensor assembly, electronics, and packaging. A draft ICD was prepared and initial design analyses carried out. A Preliminary Design Review (PDR) was held at Amptek on 20 June 06. At the conclusion of the first year, the preliminary design phase is essentially complete and we will begin critical design soon, right on schedule.

2. BACKGROUND INFORMATION

2.1. Theory of Operation

An ElectroStatic Analyzer (ESA) is a device that uses electrostatic fields to analyze a population of charged particles. The electrostatic field steers charged particles in trajectories determined by their charge state, kinetic energy, and incident velocity vector. Only particles incident with a particular energy and direction are transmitted through the ESA, i.e., the ESA acts as a particle filter by rejecting those with an unacceptable direction or energy. The energy of the transmitted particles is proportional to the electric field strength across the plates. To measure the energy spectrum, the response energy is stepped or swept over time by varying the bias voltage. In a typical application, the bias might be stepped ten times in a second to obtain a ten-channel energy spectrum every second.

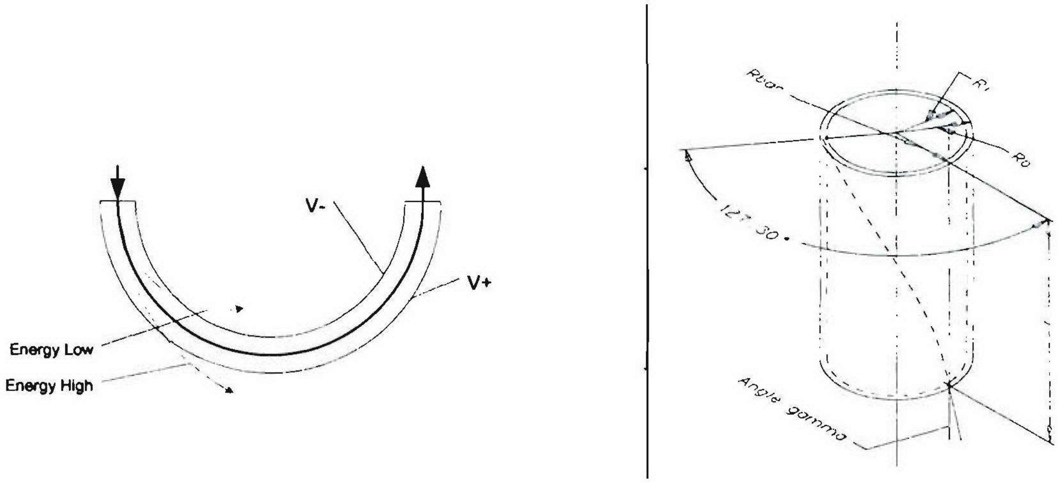


Figure 1. Sketches of ESA plates, showing the cylindrical and spiral geometries.

The ESA plates both determine the electric field and filter the particles (with additional filtering arising from entrance and exit apertures). There are many different plate geometries that have been used. Cylindrical curved plate analyzers, sketched on the left in Figure 1, have been flown on many space missions. All the particles that pass through the entrance aperture and are transmitted by the ESA plates exit at a single location, so this design provides no angular information. It is simple and has been used in many space missions for over 30 years. There are several different geometries that provide angular information, including the triquadraspherical ESA (used in several instruments Amptek has designed and manufactured for AFRL), the hemispherical, etc. Since DSX does not require angular information, these more complicated geometries are not useful. The spherical sector geometry provides no angular information but can cover a wider angular range, so it is a reasonable option for DSX.

A spiral geometry is sketched on the right of Figure 1. This is essentially a generalized version of the cylindrical geometry that offers some advantages. First, it provides a very high analyzer constant (as much as 40 or more), which makes practical a broad energy range in a small package. Second, it looks off the axis at an angle γ. One can arrange several different apertures around the perimeter of the cylinder. Since each aperture accepts particles over a cone, a large angular FOV is possible. The different apertures can be connected to different electronic channels, to obtain pitch angle information, or to a single channel of electronics, to obtain a simple, compact system with a large FOV. The spiral ESA is a variation on the conventional cylindrical ESA, which is the γ=90° limit of the spiral. In a cylindrical ESA, the particles are confined to trajectories near a plane orthogonal to the cylinder's axis. Amptek, Inc., developed the spiral ESA technology under a US Air Force SBIR contract. Other ESA geometries which have been flown include the triquadrispherical geometry, used by Amptek on the SSJ5 instrument on the DMSP spacecraft, on the SPREE instrument for the Space Shuttle TSS-1 mission, and for the LEPA instrument on CRRES; the top hat geometry flown on several planetary missions; hemispherical sector sensors used in laboratory instruments; and near planar geometries developed by Dr. Lon Enloe at the Air Force Academy. Each of these geometries is advantageous for some applications so it is critical to match the sensor selection to the detailed mission requirements.

2.2. Electronics and Data Processing

In any ESA, the plates transmit single particles, with energies as low as tens of eV. To efficiently detect these, an electron multiplier is mounted at the exit aperture. The output of the multiplier goes to an analog amplifier and a discriminator, which produces a logic pulse for each incident particle. These pulses are counted. Digital electronics control the bias on the plates, synchronizing the counters and the bias steps to determine the spectrum, and implement the serial interface. A full instrument consists of (1) the ESA itself (the curved plates and multipliers), (2) analog electronics, (3) digital electronics to count pulses, control the HV, and implement the serial interface, and (4) a power supply (see Figure 2). The power supply must provide the bias to the plates and multipliers, typically several kV, along with low voltages.

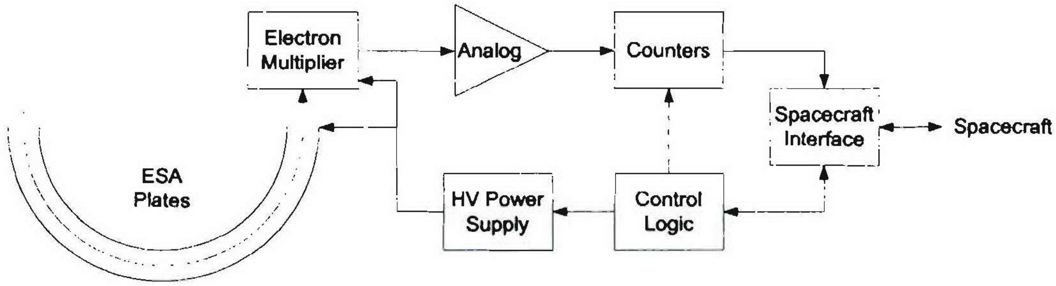


Figure 2. Simplified block diagram of generic ESA instrument, with cylindrical plates sketched.

2.3. Heritage Instrument

The SSJ4 was designed to measure the charged particles responsible for the auroral electrons and ions from 30 eV to 30 keV precipitating into the ionosphere.[i] It has flown on spacecraft of the Defense Meteorological Satellite Program (DMSP). It contains four cylindrical analyzers: one each for low (high) energy electrons (ions). The SSJ4 produces no angular information, counting all of the particles incident through the collimated aperture. The geometric factors (in (cm^2-ster)) and angular responses are shown in Table 1. The energy is swept in ten discrete steps for each plate, with one overlapping channel, producing 19 log-spaced energy channels. The readout period is 1 second. Since the SSJ4 was designed specifically for DMSP, it includes the spacecraft-specific OLS serial interface. Ten of these units have been flown in space. We consider this the heritage for the development we propose here.

Table 1. Response of the SSJ4 Instrument

	Electrons		**Ions**	
	Low Energy	**High Energy**	**Low Energy**	**High Energy**
Geometric Factor	7.1×10^{-4}	9.0×10^{-4}	1.5×10^{-2}	9.0×10^{-4}
Angular Response	2° x 7°	4° x 5°	8° x 8°	4° x 5°

3. CONCEPT DESIGN PHASE

3.1. Requirement Clarification

The first months of the program involved requirement clarification, due largely to the fact that the spacecraft and experiment goals evolved as the mission matured.

First, as was reported in the first quarterly report, a Kick-Off Technical Interchange Meeting was held on 31 May 05 at Amptek. At this meeting, AFRL made clear that, as DSX plans developed, it became desirable to use LEESA to support the Wave Particle Interaction Experiment (WPIx) on DSX along with the SWx experiment for which it was originally intended. An instrument designed for WPIx measurements is more ambitious than a pure SWx experiment with enhanced requirements. Under VLF transmissions, the plasma and particle environment changes much more rapidly and will have considerably enhanced structure in energy and in angle. Meeting enhanced requirements would likely affect the scope of the effort. Therefore, at the Kick-Off Meeting several Action Items were taken by AFRL and Amptek personnel to assess the technical and cost impacts of these changes, outline several different concepts, and report back to AFRL. This happened at the 21 November 2005 Concept Design Review, discussed below. One particular component to the enhanced requirements is a wave-particle correlator. At a meeting on 11 July 05, Amptek provided several recommendations, including the use of a design from Paul Gough, at the University of Sussex.

Second, the DSX spacecraft mission was de-scoped considerably during the first half of the year. Amptek provided information on interfaces and designs based on the initial plans and discussed this at the DSX Summer Meeting in Phoenix, AZ, from 6-10 June 05. The mission was later de-scoped, interface requirements changed, and this aspect of the design continues to evolve.

3.2. Goals and Requirements

As mentioned above, the primary requirements are to measure electrons and ions, from 100 eV to 50 keV in 20 to 30 log spaced energy bins, with a time resolution of 1-5 (5-10) seconds for electrons (protons), and with a single FOV of 25° to 50° unfocused angle. Based on the orbit, the goal of the sensitivity and dynamic range are to handle an electron (proton) flux of $1x10^5$ to $1x10^{10}$ ($5x10^4$ to $1x10^9$) $(cm^2\text{-}s\text{-}ster)^{-1}$.

AFRL considers the following enhancements to be desirable, if they can be accommodated without additional cost or risk.

- First, to extend the energy range down to 10 eV.
- Second, to make the sweep configurable – instead of always sweeping over all energy channels, with fixed timing, to be able to change the sweep levels and readout rate on orbit. This permits studying the rapidly changing environment during WPIx.
- Third, to have even wider angular range and to measure the angular distribution of the particles.
- Fourth, to measure wave-particle correlations, in order to assess energy transfer from WIPER to the thermal and suprathermal populations.

Beyond these performance requirements, the spacecraft interface and program requirements evolved considerably over the first year of this effort. A major revision to the DSX Common Requirements Document was released in April of 2006, with many details not known earlier.

3.3. Concept Design Options

3.3.1 Trade Space

From a design trade perspective, there were three nearly independent areas of the instruments design:

1) Angular response

The desired angular response (the angular range and number of zones) determines he deflection plate geometry. It drives the number of independent data processing channels and the output data array size. This is largely a function of the ESA plate geometry. There were seven different options considered during concept design:

[1] Standard cylindrical analyzers (narrow FOV)

[2] Wide FOV cylindrical analyzer

[3] Wide FOV spherical sector analyzer

[4] Multiple spiral analyzers with single (wide) zone

[5] Multiple spiral analyzers with multiple zones

[6] Standard triquadrispherical analyzer

[7] Triquadrispherical analyzer with symmetric response

2) Control and processing electronics

A configurable sweep impacts the control of the deflection plate bias voltage: the number of steps, frequency at which it steps, flexibility in reconfiguring etc. This impacts the design of the high voltage power supplies. The use of a wave-particle correlator adds considerably to the complexity of the signal processing electronics required. There were four options considered during concept design:

[1] Fixed energy sweep

[2] Configurable energy sweep

[3] Wave-particle correlator

[4] Phase angle binning of counts

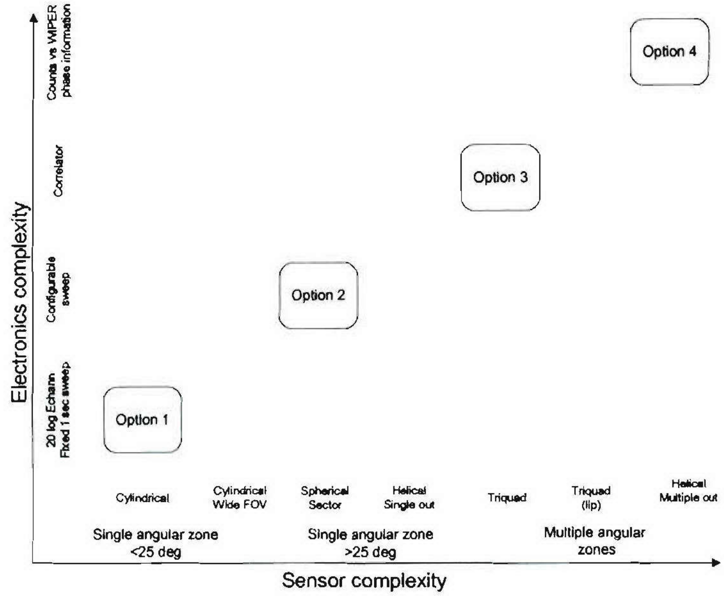
3) Spacecraft interface

The spacecraft interface includes power supplies, command and telemetry, and packaging. These elements of the design are largely independent of the other design options chosen.

3.3.2 Primary Options

In the trade study, we examined the advantages and disadvantages of the options outlined above, as presented at the Concept Design Review. The angular response and control electronic options are essentially independent, so there are essentially 4x7=28 different combined options.

We selected four of these, which spanned the trade space from the simplest and least functional to the most complex, and studied these four primary options in detail. Figure 3 and Figure 4 illustrate the trade space and the four primary options.



Primary Options

1) Cylindrical ESA with a fixed sweep
2) Hemispherical sector ESA with configurable sweep
3) Triquadrispherical ESA with configurable sweep and a wave-particle correlator
4) Spiral ESA with multiple zones and phase binning

Figure 3. Sketch illustrating the trade space and a listing of the primary options.

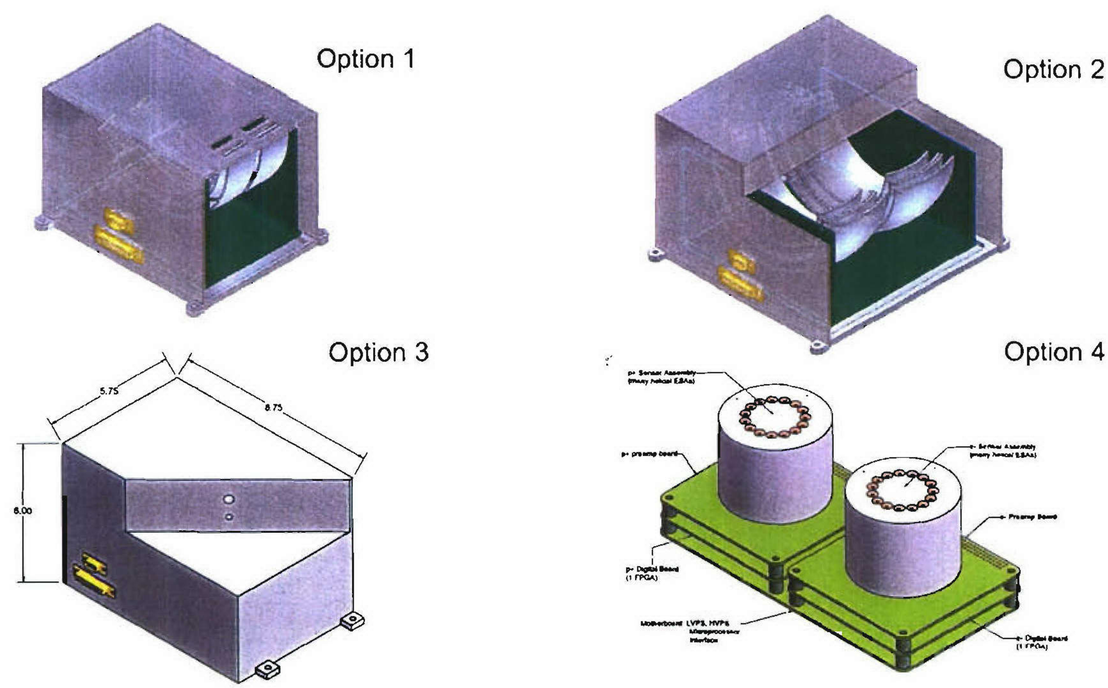


Figure 4. Conceptual drawings of the four primary options.

3.4. Concept Design Conclusions

We can summarize the analysis for these options, shown in Table 2, as follows:

1) Cylindrical ESA with a fixed sweep

This option is very similar to the heritage SSJ4. The analyzer constant would be increased to meet the 50 keV upper limit and the size changed to provide the needed geometric factor. Some of the electronic components would change, to reflect both obsolescence of the old design and new parts now available. This is the lowest risk, lowest cost, and lowest size, mass, and power. But it has little flexibility and a narrow angular range, not quite meeting requirements.

2) Hemispherical sector ESA with configurable sweep

This is similar to option (1), except that the deflection plates have a hemispherical rather than cylindrical geometry, still with a single angular zone. This is more complex and moderately expensive to fabricate but simpler than the triquadrispheres we have flown. It also has a configurable sweep, which can be implemented in an FPGA. This meets all the requirements, some of the goals, and can be accomplished within the scope of the current contract.

3) Triquadrispherical ESA with configurable sweep and a wave-particle correlator

This would be very similar to the heritage SSJ5 sensor, with multiple angular bins, but with the addition of the correlator. The correlator proposed is an FPGA implementation available from the University of Sussex, similar to what was flown on SPREE. This design provides considerable improved functionality, meeting nearly all the goals, but would be outside scope. Its cost, size, mass, and power exceed that budgeted.

4) Spiral ESA with multiple zones and phase binning

This uses non-flight proven technology to obtain the maximum angular information, with zones in two axes, and with the most sophisticated timing information. It involves the use of considerable technology with no flight heritage and the highest cost, and is outside of scope.

Table 2 - Tabulated Design Space

	J4	J5	Specs & Goals	Option 1	Option 2	Option 3	Option 4
Geometry	Cylinder	Triquad		Cylinder	Hemi Sector	Triquad	Helical
FOV (total)	4° x 10°	4° x 90°	4° x ≥25°	4° x 10°	4° x 25°	4° x 90°	90° x 90°
# Zones	1	9	1 *Several*	1	1	6	15
E_{max} E_{min} (keV)	0.03 to 30	0.03 to 30	0.1 to 50 *0.01 to 50*	0.1 to 50	0.1 to 50	0.03 to 50	0.1 to 50
Energy steps	19	19	20 *128*	20	40	32	32
Configurable	No	No	Desired	No	Yes	Yes	Yes
Correlator	No	No	Desired	No	No	Yes	Yes
PA Binning	No	No	Desired	No	No	No	Yes
Size (cm^3)	13 x 13 x 15	15 x 15 x 23		13 x 13 x 19	20 x 20 x 15	20 x 20 x 22	20 x 10 x 8
Mass (kg)	2.7	3.2	<4	2.4	3.6	4.6 kg	3.0 kg
Power (W)	0.5	1.5	<4	2.0	2.2	2.8	3.2
Telemetry (byte/s)	45	45		76	140	400	2,000
Delta cost				0	0	$600k	$1M+
TRL				9	6	6	3

Option (2) was selected as the best choice, meeting all requirements, some goals, and within the scope and budgets.

4. PRELIMINARY DESIGN PHASE

Given the basic concept, hemispherical sector electrostatic analyzers, we proceeded to the preliminary design phase. This is nearly complete, with the Preliminary Design Review scheduled for early in the second year. The key aspects to the preliminary design include (1) mechanical and electrical design of the sensor assembly, the deflection plates and multipliers; (2) mechanical design of the box packaging; (3) design of the electronics, including the analog circuitry, high power supplies, digital pulse processing circuitry, and spacecraft interface circuitry.

4.1. Sensor Design

The sensor consists of the deflection plates, the microchannel plates, the apertures, mechanical components to hold these in place, and electrical interconnects. Figure 5 shows the design of the deflection plates, which are sections of hemispheres. Table 3 gives the key parameters, including the radii, the analyzer constant, and the geometric factor.

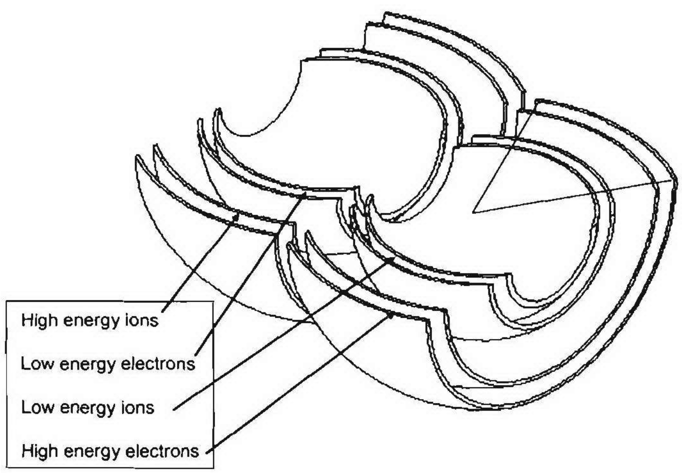


Figure 5. Drawing of the preliminary deflection plate geometry.

Table 3. Table of the key parameters of the preliminary sensor design.

		R_{bar} cm	ΔR cm	k	α deg	β deg	ΔE/E %	GF cm^2-ster	Γ	Rate (sec^{-1})
Electron	Low	4.944	0.47	10.5	3.5	25	4.8	2.1×10^{-3}	3.3×10^{-5}	3.3
Electron	High	7.644	0.725	10.5	3.5	25	4.8	5.0×10^{-3}	7.6×10^{-5}	7.6
Ion	Low	4.944	0.47	10.5	3.5	25	4.8	2.1×10^{-3}	3.3×10^{-5}	1.7
Ion	High	7.644	0.725	10.5	3.5	25	4.8	5.0×10^{-3}	7.6×10^{-5}	3.8

The upper energy limit, 50 keV, is a major design driver. To achieve this with the flight proven HV601 optocouplers requires an analyzer constant k>10. To meet high voltage creepage requirements with the necessary bias and analyzer constant, R_{bar} must be greater than 4.9 cm. This is a driver for these spheres and this sets the minimum dimension on the entire package. This does provide an adequate geometric factor.

The low energy sphere dimensions are not as tightly constrained. The preliminary design shows the same analyzer constant for all sphere sets, but this approach results in a lower geometric factor for the lower energy range. It may be preferable to reduce the analyzer constant for the lower energy sphere set, yielding a constant geometric factor. This is acceptable since the bias voltages are much lower.

We plan to use standard format microchannel plates, rather than the custom plates used on previous missions. This will reduce costs with no performance loss. The anodes will be configured so as to obtain a direct background readout using the same MCPs as the primary signal measurement.

The high (low) energy head will sweep from 50 to 2.2 keV (2.2 to 0.1 keV) using a default set of 19 log-spaced steps. Note that both heads measure the 2.2 keV channel for cross-calibration. The low energy head will have an optional setting for a lower energy sweep, from 2.2 to 0.01 keV, still in 19 log-spaced steps (Figure 6).

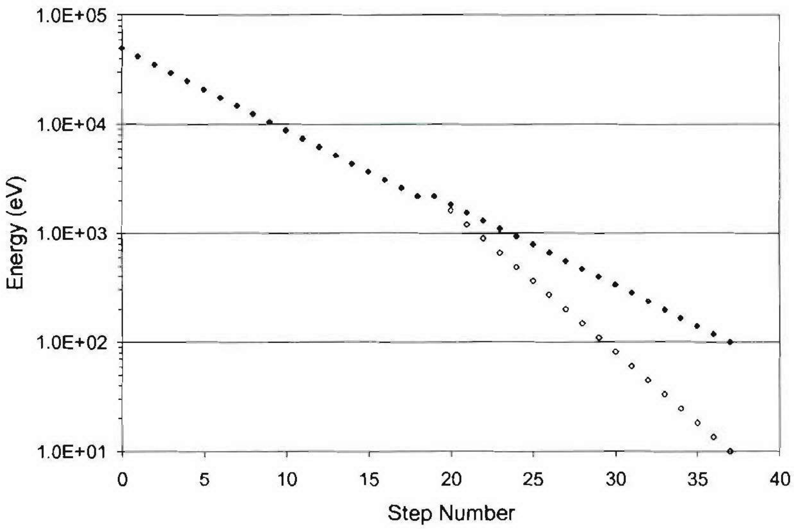


Figure 6. Plot showing the 38 energy steps available.

These 19 steps over each range are the allowable values. By default, the instrument will sweep over all 19 in each 1 second acquisition (with a 20th interval for flyback). However, the sensor can be configured by serial command to step to any of the 19 energy values in any of the 20 time bins. In this way, the sweep may be configured but the telemetry packets will be unchanged. For example, one could measure every other step and go through the sequence twice in a second to obtain higher time resolution, coarser energy resolution data.

4.2. Packaging Design

Figure 7 and Figure 8 illustrate the preliminary packaging design. The deflection plates are assembled with MCPs into sensor assemblies which are mounted on the base plate. A preamplifier board covers these, with the preamps extending into the cavity inside the deflection plates. The other printed circuit boards (high voltage power supply and spacecraft interface) are located on the front of the sensor, along with the connector. The instrument looks out to the top, with 5°x25° fields of view which must be clear. The power connector and the CM & TM connector will be identical to CEASE (the Compact Environmental Anomaly Sensor) and HEPS (the High Energy Proton Sensor). The safing plug is installed during ground tests to limit the high voltages to permit safe operation at atmospheric pressure. This is a "remove before flight item".

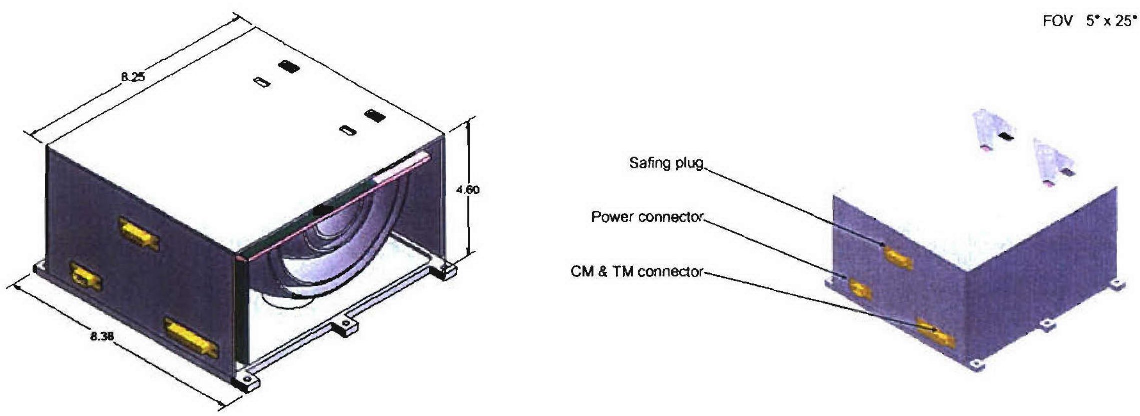


Figure 7. Drawings of the preliminary packaging design. Left: Illustration showing location of sensor assembly and boards, with one side removed. Also shows dimensions and mounting feet. Right: Illustrating showing preliminary fields of view and connectors.

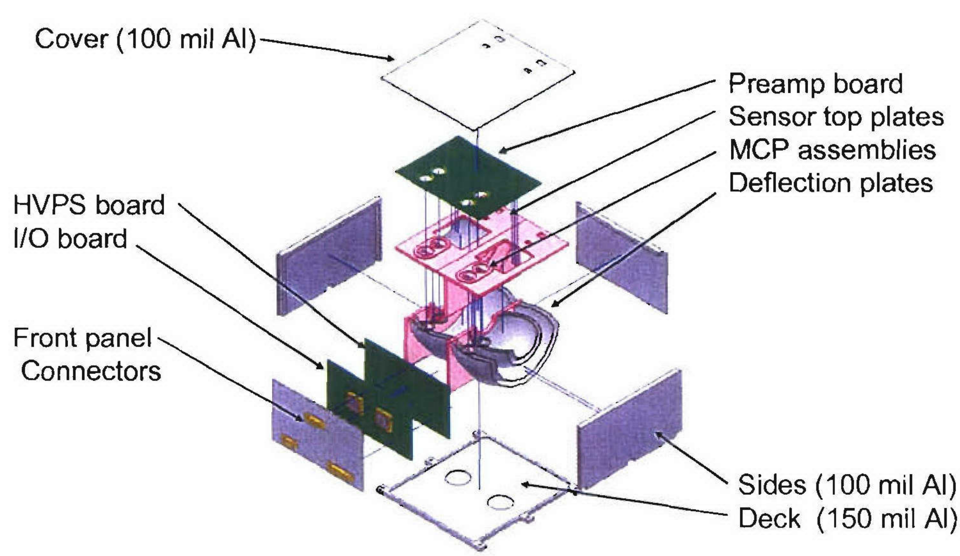


Figure 8. Exploded diagram showing the major components and how they are assembled.

4.3. Electronics Design

A block diagram of the LEESA electronics is shown in Figure 10. The major function blocks are:

1) Sensors
2) High voltage power supplies
3) Analog pulse processing circuitry
4) Calibration and test
5) Counters
6) Command and telemetry
7) Low voltage power supply

Each of these function blocks is found in any ESA instrument and the LEESA preliminary design makes extensive use of flight heritage designs. Detailed designs are shown in the PDR package. To summarize:

4.3.1 Sensors

The sensor assembly is as much mechanical as electrical and was already discussed. The only electrically active elements are the MCPs.

4.3.2 High Voltage Power Supplies

The high voltage power supplies are critical to LEESA's operation and are fairly complex. The supplies must generate deflection voltages: eight voltages (four of each polarity, balanced) which must step every 20 msec, over a dynamic range of about 25, with high accuracy and fast settling. The load currents are low. The MCPs require five bias voltages, with two of them commandable to any of eight levels, quite stable but at larger currents.

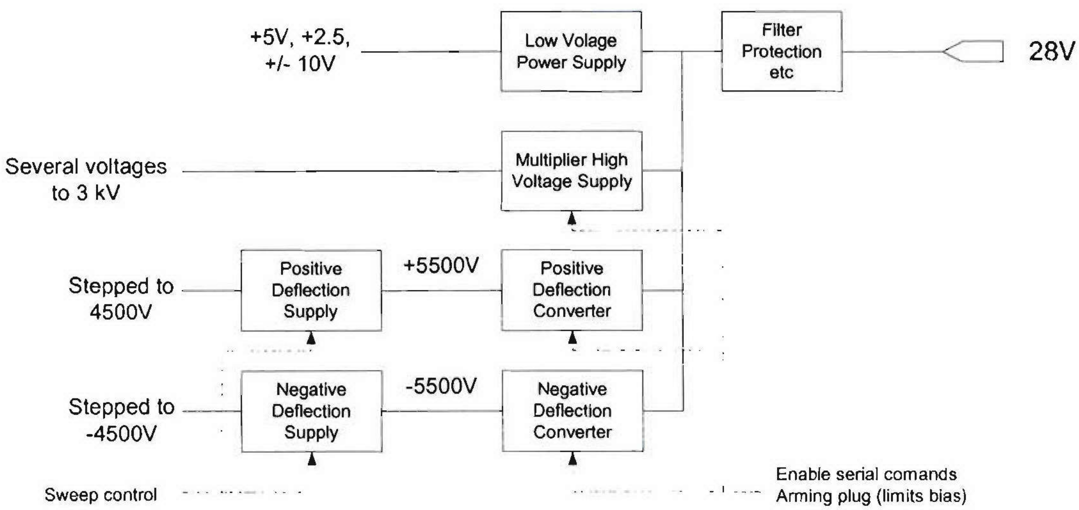


Figure 9. Block diagram of power supply.

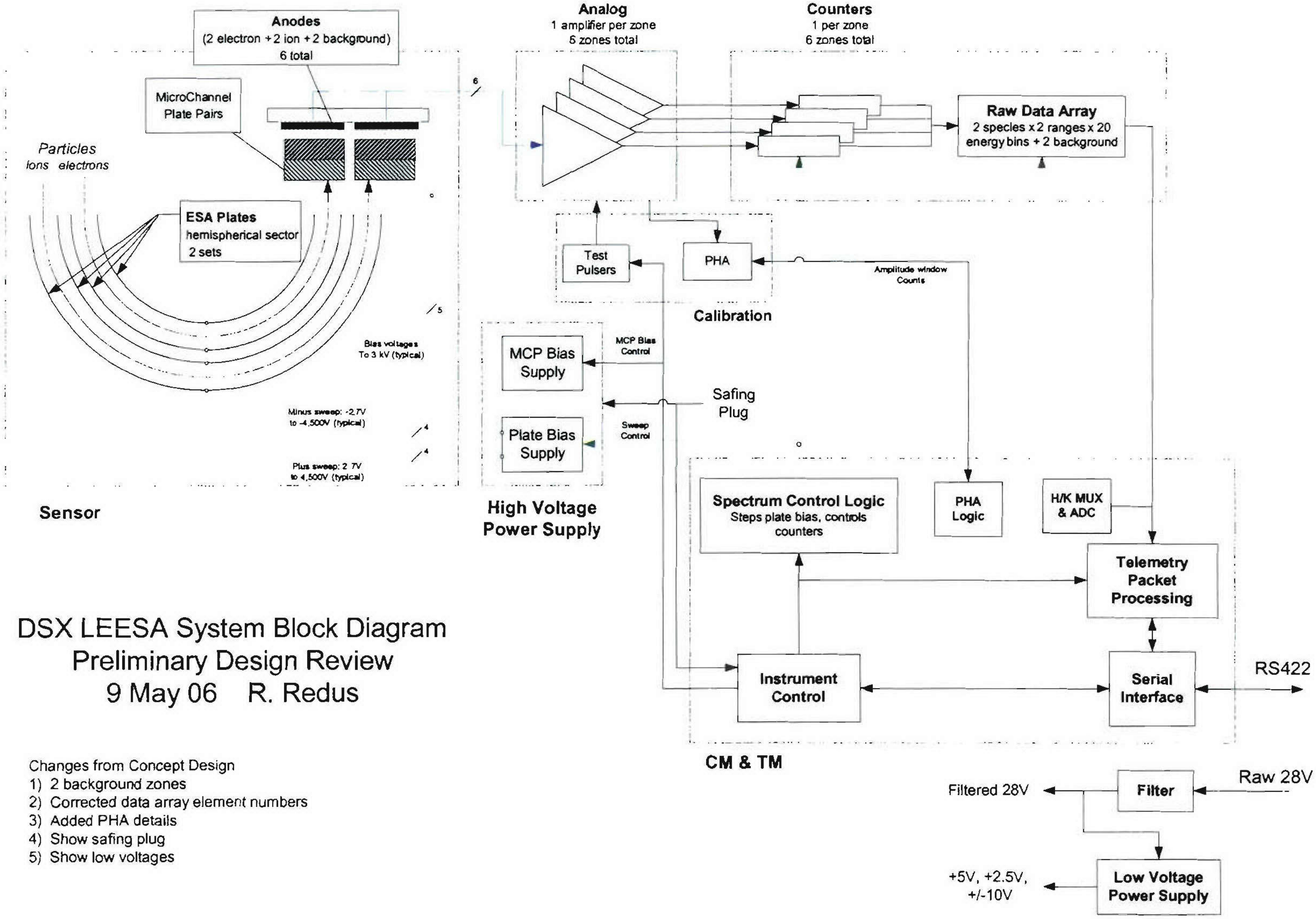


Figure 10. LEESA system-level block diagram. This drawing illustrates the 7 major functional blocks in LEESA.

The block diagram in Figure 9 shows the architecture of the high voltage power supply. The filtered 28V supply from the spacecraft is input to the three major high voltage power supplies: the MCP deflection supply and the positive and negative deflection bias supplies. Each of these is a quasi-resonant transformer coupled power supply. Each has an enable line, under control of the digital hardware and activated by a restricted serial command. In addition, each has a "safing" input which limits the bias, so that the supplies can be safely operated in air.

The high voltage supply designs will be based extensively on the heritage, both in architecture and critical components, such as the HV601B high voltage optocoupler. There are some changes planned, for example adding stages to the Cockroft-Walton multipliers to achieve the higher bias voltages, adding a separate low and high range divider set, adding a switch to achieve the 10 and 100 eV lower limits, and replacing the low voltage 4N49 optocoupler with the more radiation tolerant 6N140.

4.3.3 Analog

The analog circuitry planned for LEESA will be based on Amptek's A121 hybrid charge amplifier. This is a more modern version of the A111 used in the heritage sensors. The A121 has extensive flight heritage. There are six output channels from the sensor (low energy, high energy, and background from both electrons and ions). Each has a dedicated charge amplifier. Each charge amp will have two lower thresholds, which can be switched on orbit to compensate for MCP again. Each charge amp produces a digital pulse when the input exceeds threshold, and all six of these are sent to separate digital counters. Each charge amp also produces an analog pulse, and these are multiplexed into the calibration circuitry.

4.3.4 Calibration and Test

There are two separate functions in the calibration and test circuitry: a test pulser and a pulse height analyzer. The test pulser generates pulses to stimulate the charge amps, sweeping the amplitude to permit measurement of the lower level thresholds, to verify that the gains and thresholds are stable. We plan to implement this using an FPGA, where a PWM output from the FPGA determines the pulse amplitude, which is switched by the FPGA to generate the fast pulses. When the test circuit is enabled, the pulser would start with a sequence of low amplitude pulses, then increase the amplitude over a time of a few seconds. By counting how many pulses exceed threshold, the threshold can be determined. This is best done with the deflection and MCP bias voltages disabled, so there are no real counts recorded as well.

The pulse height analyzer is a significant improvement to the heritage sensors. In prior missions, it has been necessary to estimate gain and sensitivity losses from proxy data, which is quite uncertain. In this mission, we propose to directly measure the MCP pulse height spectra and therefore the gain. Gain changes can be directly identified. Each analog output is multiplexed into a pulse height analysis circuit under FPGA control. In the preliminary design, a PWM output from the FPGA sets a threshold, and this threshold is stepped over time. The FPGA counts pulses over the threshold, so the integral spectrum is measured, and by finding the differences, the differential pulse height spectrum is obtained.

4.3.5 Counters

Each of the six digital outputs from the charge amps is sent to a counter in the FPGA which records the number of counts in each 50 millisecond step. At the end of the step, the values are latched into memory, and then the counts are reset, and the counter paused while the high voltage stabilizes. This is a straightforward design, similar in principle to the heritage units but implemented in an FPGA instead of discrete logic.

4.3.6 Command and Telemetry

The command and telemetry serial interface to the spacecraft will be implemented in an FPGA, so no onboard microprocessor is envisioned. The actual interface will be similar to that of CEASE and HEPS: RS422 differential (non-isolated) hardware, running an RS232 protocol. There will be a fixed size telemetry packet transmitted every second. The preliminary packet definition is shown in Table 4. There will be six different serial commands, each a four-byte packet containing synch bytes, command byte, and parameter byte.

Table 4. Preliminary telemetry packet definition.

Byte	Content	Note	
0	Sync Byte 1	Value TBD	
1	Sync Byte 2	Value TBD	
2	Frame Cntr. Byte 1	24 bit frame counter	
3	Frame Cntr. Byte 2	24 bit frame counter	
4	Frame Cntr. Byte 3	24 bit frame counter	
5	Status Byte 1	HV status, sweep config, command flag	
6	Command Echo	Valid when 'command flag' active	
7	Housekeeping Byte	Multiplexed	
8	PHA & Sweep download	Multiplexed (96 PHA values, sweep values, etc.)	
9	Electron Channel 0	50.0 keV	Log compressed 4 bit exponent 4 bit mantissa
10	Electron Channel 1	42.0 keV	
11	Electron Channel 2	35.3 keV	
?	?	?	
48	Electron Channel 39	100 (or 10) eV	
49	Electron Background		
50	Ion Channel 0	50.0 keV	
51	Ion Channel 1	42.0 keV	
52	Ion Channel 2	35.3 keV	
?	?	?	
89	Ion Channel 39	100 (or 10) eV	
90	Ion Background		
91	Not assigned		
92	Not assigned		
93	Checksum LS byte		
94	Checksum MS byte		

4.3.7 Low Voltage Power Supply

For the low voltage power supply, we plan to use a modular, off-the-shelf supply rather than a custom supply, to save engineering costs. At this time, no specific module has been selected. This may have a power penalty, since standard supplies generally do not operate efficiently at the low loads of LEESA.

5. Conclusions

At this stage, the LEESA preliminary design is nearly complete. The PDR will be held early in the second year, at which point we will begin the critical design phase, with CDR planned for the fall of 2006.

The preliminary design is based very strongly on the heritage sensor, the SSJ4 flown on the DSMP spacecraft. The key enhancements include:

- Use of hemispherical sector deflection plates, for a wide response in the unfocused angle.
- Higher analyzer constant and deflection plate bias voltages for a 50 keV upper limit.
- Use of standard format microchannel plates rather than custom parts. Standard parts are now Long-Life™, which will offer improved stability and accuracy.
- Addition of background channels to directly measure the background response.
- Addition of a pulse height analyzer to directly measure MCP gain changes.

Other changes are largely related to the replacement of obsolete parts, use of enhanced parts now available, and changes demanded by the spacecraft and/or mission requirements.

REFERENCES

[i] T.L. Schumaker, D.A. Hardy, S. Moran, A. Huber, J. McGarity, J. Pantazis, *Precipitating ion and electron detectors (SSJ/4) for the Block 5D/Flight 8 DMSP satellite*, AFGL-TR-88-0030 (1988)